modifications, and equivalents as may be included within the spirit and scope of the invention as defined by the appended claims.

CLAIMS

What is claimed is:

1. A Machine for Production of Granular Silicon comprising:

a heating section located below a reacting section; where said heating section can consist of one or more tubes heated by one or more heaters

a mechanism that pulses granules back and forth between the heating and reacting sections ;

separate injection of silicon containing gases and non silicon containing gases;

heating the non silicon containing gases above the reaction temperature;

cooling each injection location of the silicon containing gases;

2. a machine of claim 1 where there are multiple stages each one consisting of a heater and reaction section; where each reactor section has one or more injection nozzles for gases which promote additional reaction, in the silane reactor the gas to the reaction section would be silane, for the hydrohalosilane, e.g. trichlorosilane or tribromosilane, reactor the gas to the reactor section could be the hydrohalosilane alone, hydrogen alone or a combination of the two

3. a machine of claim 1 or 2 which recovers heat from granules by direct contact with a high purity non silicon depositing or reacting gases: such gases

can be hydrogen, helium, argon, nitrogen, silicon tetrachloride and silicon tetrabromide and must be low in carbon and oxygen containing contaminants, such as oxygen, water, carbon monoxide, carbon dioxide and methane, which contaminants must be below 1 ppmwt and preferably below 10ppbwt. Gases such as silicon trichlorosilane and silane are not usable because they decompose, hydrogen chloride, hydrogen bromide or mixtures of gases, which react such as a silicon tetrachloride, and hydrogen mixture are not usable because they can react with the granules

4. a heat exchanger in which silicon containing gases are heated by hot liquid or condensing vapor maintained within a temperature range which cannot cause decomposition of the gases ;which temperature range is typically between 200-400 C but more particularly between 300-350 C

5. a sieving device by which silicon granules are sieved using one or more sieves manufactured from non contaminating sieve material and undersized granules returned to reactor ; where the noncontaminating sieve material is selected from materials which contain silicon such as single crystal silicon, polycrystalline silicon, silicon oxide, silicon nitride, silicon oxynitride and silicon carbide and where the abradable surfaces are low in contaminants such as boron, phosphorus, aluminum, arsenic, iron, copper and other metals, such contaminants will typically be below 1000 ppmwt and preferably below 100 ppmwt

6. an optional feedstock recovery section; where a silicon quadrahalide such as silicon tetrachloride or silicon tetrabromide is injected, mixed with the reactor effluent then quenched at an optimal temperature to recover the silicon hydrohalides such as trichlorosilane and dichlorosilane

7. one or more cooled joints between external equipment and the reactor which transmit hot gases or solids. and which are cooled using localized, one or more, microchannels positioned to primarily cool the elastomeric O-ring to a temperature such that decomposition of the O-ring or increased permeability of the o-ring to oxygen ,water and carbon dioxide does not cause significant contamination without excessive heat loss , such temperature is typically 25-300 C and preferably 50-150 C for o-rings made from high purity fluorocarbon o-rings such as Viton, Kalrez and Teflon

8. a machine of claim one or two where there is external flow control of each injection point, such flow control may be direct with flow control of each nozzle done independently, indirect by means of a flow distribution device such as a manifold or a combination of the two where some nozzles are ganged in groups

9. a machine of claim 8 where the shape of the pulse and/or the distribution of flow between nozzles may be adjusted to control the generation of new particles without changing the total flow

10. a preferred variation of claim 8 where the flow of gas to each nozzle is controlled before the heater/s and an even more preferred option where multiple separate flows are heated in the same heater

11. a preferred combination of the above claims for the use of silane as a feedstock, where there are; two or more stages; high purity hydrogen is used for the non silicon containing gas to the first heating section, for the cooling of the granular silicon and for return of undersize granules to the reactor; the sieving device is made from high purity quartz tubes and polycrystalline silicon sieves, the feedstock recovery system is not used; cooled joints are used for all the inlets and outlets of the reactor; the silane heat exchanger uses a condensing vapor

maintained in the temperature range 340-360 C and each gas injection location is independently controlled.

12. a preferred combination of the above claims for the use of trichlorosilane and/or dichlorosilane as a feedstock, where there are; two or more stages; high purity hydrogen is used for the non silicon containing gas to the first heating section and to the second reacting section, for the cooling of the granular silicon and for return of undersize granules to the reactor; the sieving device is made from high purity quartz tubes and polycrystalline silicon sieves, the feedstock recovery system is used and silicon tetrachloride is injected to cool the effluent from 1100 C to 900 C and recover hydrohalosilanes for recycle ; cooled joints are used for all the inlets and outlets of the reactor; the chlorosilane heat exchanger uses a condensing vapor maintained in the temperature range 340-360 C and each gas injection location is independently controlled

13. a variation of claim 1,2,11 or 12 where the heater section is of smaller diameter than the reactor section above it and connected by a tapered section, angle of said tapered section to be between 10 and 80 degrees from the vertical and preferably between 30-60 degrees from the vertical

14. a variation of claims 1,2,11,12 and 13 where the heaters used in the heating sections may be resistance heaters, inductive RF heaters, microwave heaters, lamp heaters or lasers but are preferably resistance heaters

15. a further variation of claims 1,2,11,12 and 13 where a high efficiency cyclone is used to remove dust from the effluent gases and to provide residence time for the feedstock recovery system when this is used

16. a yet further variation of claims 1,2,11,12 and 13 where a silicon etching gas or mixture of gases may be injected through one or more nozzles for the purpose of etching wall deposits from all or part of the reactor, such gases

may be elemental halides such as chlorine or bromine, hydrogen halides such as hydrogen chloride or hydrogen bromide or combinations of hydrogen and silicon tetrahalides such as silicon tetrachloride or silicon tetrabromide

17. a additional improvement to the above claims where the reactor is supported upon a weigh cell, capable of weighing the reactor and contents and measuring the intermittent force exerted by the pulsing gas and the connections to and from the reactor are flexible enough to allow the slight deflection required by the weigh cell, said deflection to be less than 1mm and preferably less than 0.5mm, and the thermal expansion of the reactor relative to the support structure, said thermal expansion to be less than 1" (25mm) and preferably less than 1/4" (6mm)

18. a further variation on the above claims where all or a portion of the non silicon containing gases are heated to a temperature below the reaction temperature outside the heating section then heated to a temperature above the reactor temperature inside the heater prior to entry to the reactor section

19. a yet further variation of claims 12 and 13 where the second stage heater section does contain some residual silicon dust or silicon containing gases from the first stage reactor section that can form a wall deposit

20. a variation of claim 5 where the sieving and return of undersize granules is done on a batch basis